NASA SPoRT Land Information System Products for Soil Moisture Analysis

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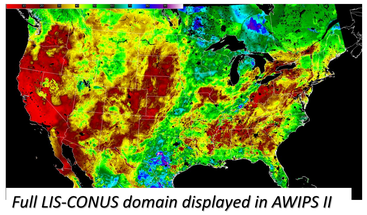
Abstract / Introduction

The NASA SPoRT Program has been producing a real-time instance of NASA's Land Information System (hereafter SPoRT-LIS) since ~2010, which contains output of soil moisture and temperature at layered depths, as well as layers of soil moisture percentiles and snow water equivalent. The unique configuration of the SPoRT-LIS enables decision-making on operational timescales since it incorporates near real-time operational observations such as the daily NOAA/NESDIS VIIRS Green Vegetation Fraction and the combined radar+gauge Multi-Radar Multi-Sensor (MRMS) QPE. The SPoRT-LIS was developed initially to provide land surface initialization variables for local numerical weather prediction models, such as the Weather Research and Forecasting (WRF) model. The earliest documented uses of the SPoRT-LIS as a tool for local drought analysis came from the NWS forecast office in Huntsville, AL in 2011, in which data were used to provide recommendations for drought category changes to the U.S. Drought Monitor. Through engagement with SPoRT collaborative partners, the SPoRT-LIS gradually expanded in recent years as a component of drought analysis to the U.S. Drought Monitor. Other applications over the years have included using SPoRT-LIS in qualitative pluvial analyses, assessing land surface conditions leading to wildfires, and use by State Climatologist offices. This poster provides examples of applying the SPoRT-LIS for drought analysis, fire weather, and pluvial / flood assessments, which served to motivate the development of machine learning applications (see Andrew White presentation).

- Continually-restarted long-term Noah LSM simulation from 1981 to present
- Meteorological forcing inputs: (real-time cycle restarts every 6 hours)
  - ✓ Hourly 0.125° NLDAS-2 from 1981 to t – 4 days, ~4-day latency of NLDAS-2 in real-time
  - ✓ Global Data Assimilation System analyses/short-term forecasts & MRMS from t-4 days to present
  - ✓ LIS forecasts out to 2 weeks, driven by GFS forecast forcing
- Ingests daily real-time, global NESDIS/VIIRS 4-km Green Vegetation Fraction (GVF)
- Daily 1981-2013 soil moisture climatology
  - ✓ 0-2 m total column climatology for every CONUS county
  - ✓ Cumulative layers at every grid point (0-10cm, 0-40cm, 0-1m, 0-2m); 1-week moving window
- Data available via web portal for WRF initialization, web graphics, and AWIPS II
  - ✓ SPoRT-LIS website: https://weather.msfc.nasa.gov/sport/case_studies/lis_CONUS.html
  - ✓ GRIB2 real-time files posted to https://geo.nsstc.nasa.gov/SPoRT/modeling/lis/conus3km/ and https://geo.nsstc.nasa.gov/SPoRT/modeling/lis/conus3km/awips/



Full LIS-CONUS domain displayed in AWIPS II

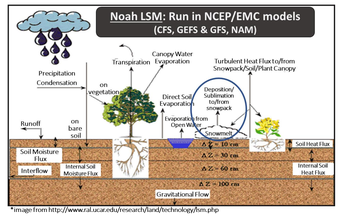
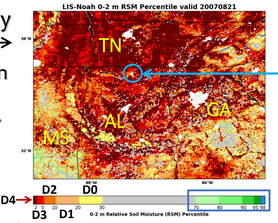
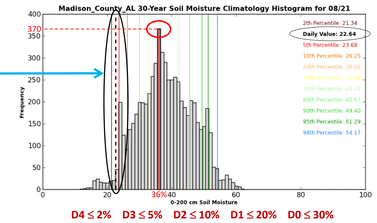


*Image from http://www.ral.ucar.edu/research/land/technology/lsm.php

SPoRT-LIS Climatology & Percentiles, Real-time Configuration, and Future Endeavors

Daily Soil Moisture Climatology by County



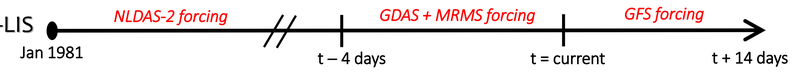


Additional details can be found in the LIS "primer" and percentile product modules at links below.

LIS Primer QR:

Percentile Module QR:

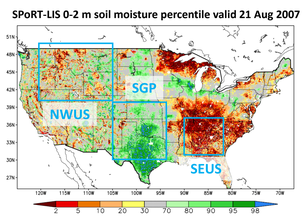
Real-time SPoRT-LIS Timeline



Future Plans / Ideas for SPoRT-LIS

- Upgrade to Noah-MP with ingestion of real-time satellite VIIRS vegetation (Leaf Area Index)
- Implement an improved blended QPE for reduced artifacts caused by NLDAS-2/CPC input precip analyses
- Expanded machine learning applications: e.g., wildfire and/or convective initiation
- Develop ensemble LIS driven by GEFS forcing for probabilistic guidance and S2S/Flash drought prediction

Proxy Drought Validation and Stakeholder Application

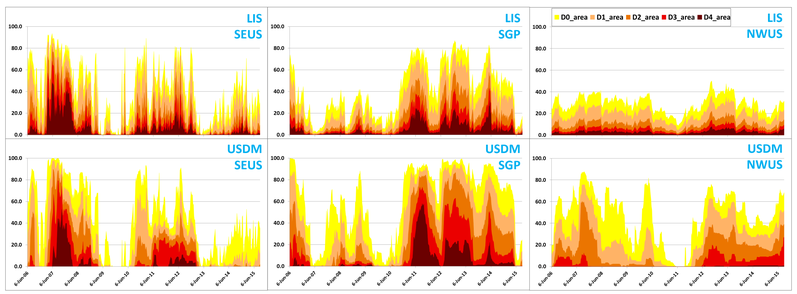


Difference in mean area (SPoRT-LIS minus USDM)

Bias	D0	D1	D2	D3	D4
SEUS	-4.1	2.1	0.2	0.7	2.4
SGP	-19.8	-14.0	-12.5	-6.6	-1.2
NWUS	-17.4	-8.6	-4.5	1.4	2.6

Correlation	D0	D1	D2	D3	D4
SEUS	0.89	0.87	0.85	0.83	0.72
SGP	0.90	0.90	0.88	0.83	0.70
NWUS	0.77	0.68	0.53	0.38	0.12

SPoRT-LIS 0-2m soil moisture percentile proxy drought category verification. (Above-Left) Select CONUS verification regions; (Above-Right) Bias and Correlation statistics from 2006-2016; (Below) Time series of area coverage of SPoRT-LIS proxy drought categories [top row] versus area coverage of USDM drought categories from 2006-2016.

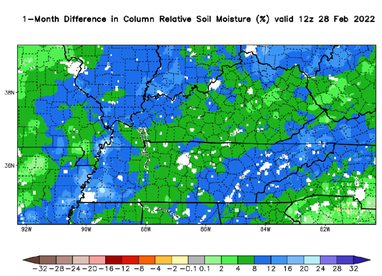


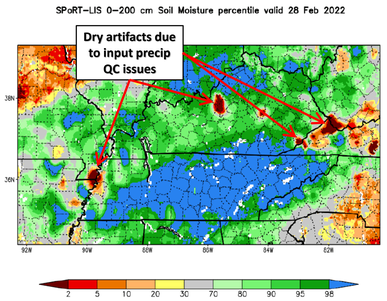
(At right and below) Example of the Tennessee State Climate Office incorporating SPoRT-LIS information into their February 2022 monthly climate reports. Soil moisture exceeded the 98th percentile across most of Tennessee by late February, due to excessive rainfall during much of the month. Note dry artifacts due to QC issues of input CDC and NLDAS-2 precipitation forcing.

February 2022 Tennessee State Climate Summary

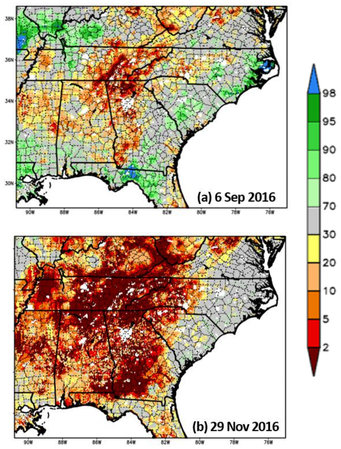
Soil Moisture:

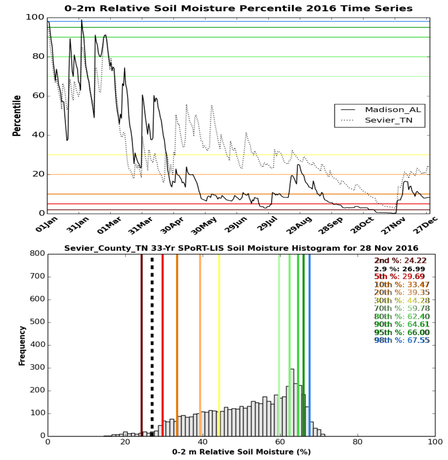
On February 22, the USDA Crop Progress report indicated that topsoil moisture in Tennessee was 6% short, 75% adequate, and 19% surplus, and subsoil moisture was 5% short, 80% adequate, and 15% surplus. However, another week of heavy rains during the last week of February will likely remove all shortages from topsoil moisture across the state. The NASA SPoRT Land Information System shows that integrated soil moisture across the top two meters of the ground is above normal in almost all areas of the state, reaching up to the 98th percentile in all areas in blue in the map below. This represents an increase of 4-20% from the end of last month.





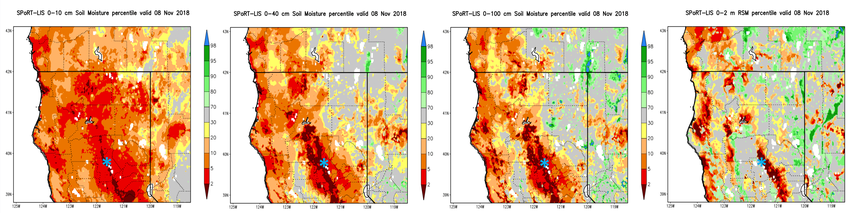
Wildfire Applications

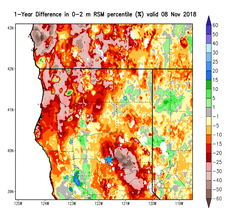




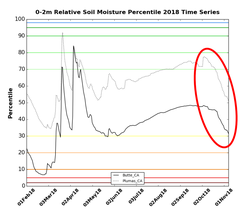
(Above) Soil moisture conditions leading up to the Gatlinburg, TN wildfire event of 28 Nov 2016. (Left) Change in SPoRT-LIS soil moisture percentiles from 6 Sep to 29 Nov 2016; (top-right) Time series of county-averaged soil moisture percentile for Madison County, AL and Sevier County, TN during 2016. (lower-right) Sevier County, TN soil moisture climatological histogram for 28 November, with county mean soil moisture (bold dashed line) on 28 Nov 2016. [From Case et al. 2018; Results in Physics]

(Below) Layered soil moisture percentiles associated with the deadly California Camp Fire of 8 November 2018 [From Case et al. 2019; AMS annual meeting; 33rd Conference on Hydrology]



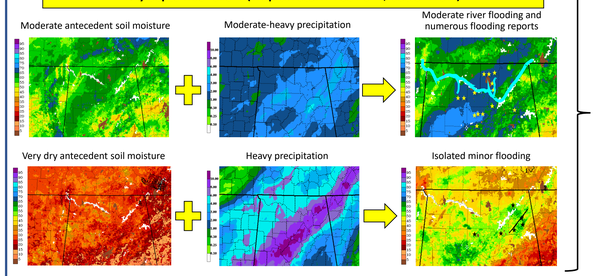


(Left) One-year change in 0-2m soil moisture percentile. (Right) Sharp declines in county-averaged 0-2m soil moisture percentiles leading up to Camp Fire [From Case et al. 2019; AMS annual meeting; 33rd Conference on Hydrology]



Pluvial and Tropical Cyclone Impact Applications

A tale of two antecedent soil moistures: Wet March 2011 event (top row) vs. Dry September event (Tropical Storm Lee 2011; bottom row)



- Classic contrasting example on importance of pre-existing soil moisture conditions.
- Initial qualitative thresholds applied to interpretation of flooding threat.
- Provided impetus for developing machine-learning solutions to predict stream gauge height (See A. White presentation)

Above example from Land Information System Applications training module:

(Below) Analyses of Tropical Cyclone Extreme Rainfall (from Case et al. 2021; JoM)